Enterprise Energy Management System Installation Case Study at a Food Processing Plant

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1. Introduction

Enterprise Energy Management (EEM) System is a combination of software, data acquisition hardware, and communication systems to collect, analyze and display building information to aid commercial building energy managers, facility managers, financial managers and electric utilities in reducing energy use and costs in buildings. This technology helps perform key energy management functions such as organizing energy use data, identifying energy consumption anomalies, managing energy costs, and automating demand response strategies. Compared to other data archive and visualization systems, EEM is more tied-in to business enterprise information such as; facilitating energy benchmarking, optimizing utility procurement, and managing overall energy costs. Figure 1 illustrates concept of EEM system architecture.

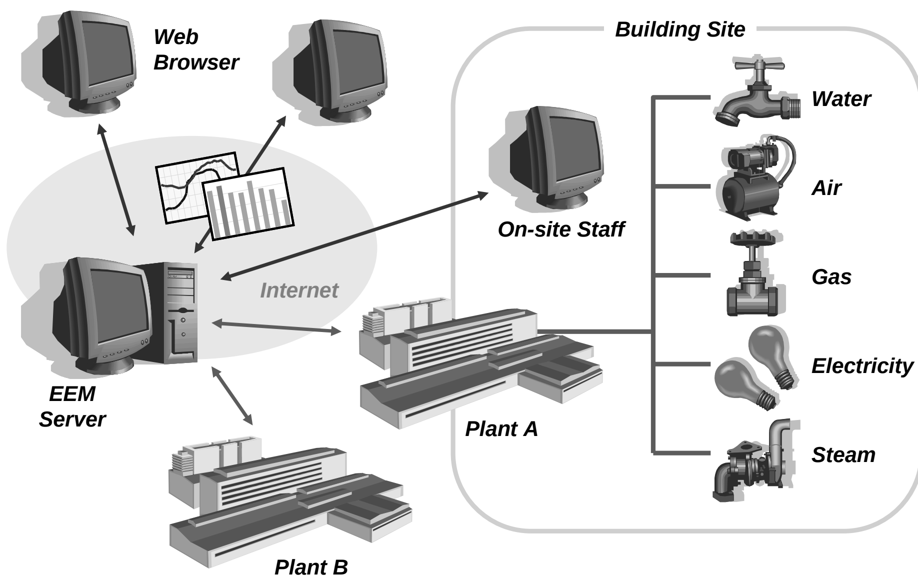

Figure 1: Enterprise Energy Management System

During recent years, numerous developers and vendors of EEM have been deploying these products in a highly competitive market. EEM offer various software applications and services for a variety of purposes. Costs for such systems vary greatly depending on the system's capabilities and how they are marketed.

In spring 2004, Del Monte Foods received funding from State Technologies Advancement Collaborative (STAC) to install an EEM system at one of their food processing plants. Del Monte asked Lawrence Berkeley National Laboratory to evaluate the EEM vendors. LBNL has been conducting survey and research on EEM (Motegi, 2003). Role of LBNL in this project is to develop a specification framework of EEM and its selection criteria and procedures, through the food processing plant's case study.

2. Site Characteristics

Del Monte chose a food processing plant in California central valley to install the EEM. The plant has 1.2 million ft^2 of total building area. Plant operations experience seasonal peaks during the summer months. The maximum demand is approximately 6.5 MW.

Requirement for EEM

Addition to the common EEM data management, visualization and analysis features, Del Monte requested several key features which are critical to their plant operation. First, the EEM had to be capable of managing data from a range of supporting systems, including water, compressed air, gas, electricity and steam, also referenced as "WAGES". Second, the interoperability between the EEM and existing systems had to be established. The plant already had an Enterprise Asset Management System (EAM)[1] and forklift battery charger system. The data from these systems needed to be fed into the EEM system as well. Third, the EEM system had to be expandable for potential nationwide installation and networking. The company views this EEM installation to this plant as a pilot project for future nationwide installation.

3. Vendor Selection

Role of LBNL in this project was to compile a list of EEM vendors and to assist the company in evaluating their products by various criteria. Twenty-seven EEM vendors were listed by LBNL, and evaluation process took several steps from preliminary to final.

The preliminary evaluation was performed by reviewing the vendors' website followed by a telephone interview. The secondary evaluation was to ask vendors to answer a questionnaire form prepared by LBNL. The questions include vendor profile, connectivity, metering, integration, data security, data visualization and analysis, graphical display, demand response, utility procurement management, financial analysis, and reporting capability. The filtering criteria were based on the company's requirements and LBNL expertise. Many detailed questions were asked on features of data analysis web-base tools, and experience and strength in industrial grade metering and control products. Upon completion of the secondary evaluation, the vendors were filtered down to four candidates.

For the final evaluation process, Del Monte sent a request for proposal (RFP) to the four vendors. Prior to the RFP, web demonstrations were also conducted. LBNL helped the company evaluate the proposals. Through the RFP evaluation process, one vendor couldn't provide requested features within the budgetary allowance. The web demonstrations of two other vendors were somewhat unfocused on EEM features as a pre-developed tool. The winning vendor's demonstration covered most of what the company requested, showed flexibility for future software feature expansion, and was well-developed. Interestingly, two of the vendor finalists decided to partner with each other for this project, and the winning vendor company was purchased by the fourth

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[1] Enterprise asset management (EAM) is the organized and systematic tracking system of an organization's physical assets including plant, equipment and facilities for productivity enhancement, maximizing asset life cycle, and minimizing total cost.

finalist vendor company during the evaluation process. This shows the dynamic changes in the current EEM industry.

EEM Vendor Selection Criteria

In the secondary selection process, various questions about the characteristics of the EEM products were asked of the vendors. The questions included vendor profile, metering and connectivity, and application capabilities. Each question was weighted based on the client's preference, and total score was calculated for each vendor. The following list presents the questions used to evaluate each vendor during the selection process.

1. ***Vendor profile*** -
    a. **Does the vendor have several years of experience and a stable business history in the particular EEM related services?** It is important to receive continuous maintenance from the vendor after installation.
    b. **Does the vendor have experience working with industrial customers?** It is more important to assure precise installation and operation in industrial sites than in commercial buildings. Experience in industrial applications is critical. Experience in similar type of industrial facility, for instance food processing or bio-tech, will be plus.
    c. **Is the vendor capable of single source responsibility?** Make sure that the vendor manages from hardware installation to application customization as a turn-key contractor.
    d. **Does the vendor have a regional office in the state?** A regional office nearby is useful to get hands-on support from the vendor during and after the installation.
2. ***Connectivity*** -
    a. **Does the vendor have capability for two-way communication flow (monitoring and control)?** All EEMs should have monitoring capability, while some of them may offer remote control capability as well.
    b. **What types of data input are supported by the EEM?** Types include: Pulse, 0~10 Volt DC, 4~20 mAmp, Digital, etc.
    c. **What types of metering/communication protocol are supported by the EEM?** Types include: TCP/IP, BACnet, LonTalk, Modbus, Profibus, etc. If your facility uses some specific protocol or has some native equipment for the specific protocol, compatibility between the system and the EEM will enhance their performance.
3. ***Metering*** -
    a. **What type of data is the EEM designed to monitor/archive?** Although most of EEM products can be customized to archive any kind of data, some EEMs may focus their functionalities on specific data types such as whole building electricity, gas or other utilities. If you are planning to perform more detailed diagnoses, built-in analysis functions for electric sub-meter, pressure, or temperature data will be helpful. Calculated data points and the capability

to create a virtual data point from real measurement point values, are also helpful.

b. **What is the system response speed**? In general, communication response speed for industrial grade system is 200 ~ 500 ms or less, and commercial grade is 1 ~ 2 seconds. For only monitoring purpose, a slower response speed is acceptable, while industrial control requires faster response speed than commercial.

4. ***Database -***

   a. **What is the database compatibility for the EEM?**: Is it compatible with the following systems:

      i. Web-service client with eXtensible Markup Language (XML)

      ii. OLE for Process Control (OPC)

      iii. Open Database Connectivity (ODBC) compliant to interface 3rd party software application

      iv. Structured Query Language (SQL)

      v. Application Program Interface (API) to communicate with specific field devises such as hand-held equipment

   b. Is the database and the data transfer through the Internet encrypted?

5. ***Application capabilities –***

   What package of web application tools is available to visualize and analyze the trend data? Most EEM vendors customize their application to meet the users' needs, while they usually have built-in standard applications which are well-tailored and easy-to-use. Even if a vendor claims that they can offer any type of analysis tool as their customized solution, the customized features could be immaturely designed or costly. LBNL published a report which describes some of the application capabilities in detail (Motegi et al, 2001). Listed below are the application features which were found in existing EEM products as their built-in application.

   a. **Graphical display**: shows geographical location of site or equipment in a site.

      i. <u>Geographical site/building display</u>: Display building locations, site drawings, etc so that remote users can get better sense of the site.

      ii. <u>Graphical equipment monitoring</u>: Display mechanical system diagrams and show real-time equipment data (temperature, pressure, status, etc) in the graphics.

      iii. <u>Summary view of equipment status</u>: Summarize key equipment parameters on one screen.

   b. **Data visualization/analysis**: visualize the trend data in meaningful fashion by using Excel-like charts and graphics.

i. Daily profile: Time-series daily load profiles are displayed with time, in intervals of an hour or less, along the horizontal axis and load along the vertical axis.

ii. Day overlay: Overlay plots display multiple daily profiles on a single 24-hour time-series graph.

iii. Multi-point overlay: Allows viewing of multiple time series data points on the same graph.

iv. 3D surface chart: Three-dimensional surface charts often display the time of day, date, and variable for study.

v. Calendar profile: View up to an entire month of consumption profiles on a single screen as one long time series.

vi. X-Y scatter plots: X-Y scatter plots are useful for visualizing correlations between two variables.

vii. Basic statistical analysis: Perform statistical calculation, such as mean, median, standard deviation, correlation, ANOVA, and regression.

viii. Benchmarking: Benchmark against building energy standards/codes, or public database such as EnergyStar.

ix. Intra/inter-facility comparisons: Benchmark against the building's historical data, or across multiple buildings in the enterprise.

x. Aggregation: Aggregate data among multiple data points. Integrate different energy units using energy conversions (ex; kWh, Therm, etc into Btu).

xi. Data mining (data slice/dice/drill-down): Sum-up/drill-down time-series data by monthly, weekly, daily, hourly, or trended interval.

xii. Normalization: Normalize energy usage or demand by some factors such as building area, number of occupants, outside air temperature (OAT), and cooling or heating degree-days (CDD, HDD), to make a fair comparison between buildings.

xiii. Hierarchical summary: Summarize usage and cost information by different levels. For example, starting from equipment energy cost, individual building energy cost, site energy cost, to regional energy cost.

c. **Advanced analysis**: offers more specific analysis than the "data visualization/ analysis" mentioned above. This type of analysis often takes multiple data points and use more complicated algorithms.

i. Power quality analysis: Monitor the voltage or current phases for conditions that could have adverse affect on electrical equipment.

ii. Steam charts: Calculate temperature, pressure, specific volume, and enthalpy for saturated steam and water.

iii. Refrigerant charts: Create psychometric chart for refrigerant type dehumidification application. Used for refrigeration diagnostics.

iv. Forecasting: Forecast future trend by historical data and related parameters. Briefly explain the forecasting method (ex; regression model, neural network).

v. Validation, editing, estimation (VEE): A process performed to ensure quantities (kWh, kW, kVar, etc.) retrieved from meters or interval data recorders (IDR) are correct. The process includes validation of data within acceptable error tolerances, editing or correcting erroneous data and estimating missing data.

vi. Equipment fault detection diagnostics: Detect equipment failure or degradation based on customized algorithm and parameters.

d. **Utility cost analysis**: provides tools to analyze their utility bills by cutting-and-dicing in various manners.

i. Invoice verification (bill validation): Utility bills are compared to meter readings to validate accuracy of bills.

ii. Energy cost drilldown: Using energy tariff and usage data, calculate daily or hourly energy cost breakdown, while usually cost can only be seen in monthly total.

iii. Real-time cost tracking: Calculates electricity costs every day or hour using real-time meter reading and rate tariffs.

iv. End-use cost allocation: According to user-defined parameters and algorithms, estimates end-use energy consumption from whole building energy. Generally used for cost allocation to building tenants. A common parameter definition is energy use per square foot.

e. **Procurement management**: provides utility procurement information and analysis tools to develop better procurement plan and save utility bills.

i. Rate engine/utility tariff integration: Software contains a series of rate tariffs to fit to clients' utility rates. Users can compare energy procurement alternatives. The rate tariffs are; manual input, pre-programmed, or online tariff data acquisition.

ii. WAGES cost forecasting: Forecast future WAGES cost based on future usage forecast and energy cost trend. Performed by component level and/or whole building level.

iii. Real-time pricing functionalities: Integrate real-time pricing information into procurement process.

iv. WAGES cost what-if analysis: Compare current and alternative energy procurement scenario by applying different WAGES tariff/forecast to past, current or future WAGES usage.

v. Buy/wait suggestions: Based on energy wholesale market trend, weather forecast, and onsite stock, suggest when and which utilities to purchase energy.

f. **Reporting**: provides data exporting and alarming functionalities.

i. Data export: Export data to manually analyze the trend data or generate a ready-to-use report. Data outputs include; Excel (raw data), Access (database), Word (report), and PDF (report).

ii. Customized alarm module: Detect anomaly data and send alarm via e-mail, pager, mobile, etc.

iii. Dashboard functionality: Display selected parameters in small window application which stays on PC screen or task tray, so that operators can notice an alarm quickly.

6. ***Demand response***: Needs for demand response capabilities are increasing in both commercial and industrial facilities in recent years. Demand response functionalities include communication with utilities, automated/remote control, and event analysis.

    a. **DR communication**: Enable communication with utilities or DR aggregators including notification of DR event via website, e-mail, phone, pager, cell phone, etc, and bidding to DR event via website.

    b. **DR control**: Execute demand-shedding operation with; remote manual operation, semi-automated control by time-schedule, or fully-automated control by parameter/external signal.

    c. **DR event analysis**: Analyze DR event by using web application tools.

i. Event report: Track and report kW savings and cost for all events.

ii. Baseline calculation engine: Calculate baseline based to utility program formula.

iii. Saving calculation by tariff: Calculate saved demand and program incentive/penalty based on baseline and program tariffs.

4. Final Design of EEM

Due to the limited budget, Del Monte decided to focus on monitoring three systems for the pilot installation, to be able to partially perform system diagnostics. The targeted systems were the compressed air supply, the booster house pumps, and the electric fork lift fast charging. They also measured a few key points for electrical supply, gas, and steam, although points will be need to be added later to allow for analyses of systems performance across all WAGES (water, compressed air, gas, electricity, and steam) categories for the plant. Table 1 shows the list of the measurement points included in the initial EEM. This includes existing measurement points for the boiler temperature, pressure, and flow as well as inputs from the forklift charger management system.

The EEM is also designed to interface the existing EAM system. The EEM extracts the production data from the EAM, and makes the data available on the EEM analysis.

Table 1: List of EEM Measurement Points

Category	Component	Measured point	Unit
Air	Compressed air	Airflow	CFM
		Air pressure	PSI
		Air temperature	°F
Electricity	Utility main	Power demand	kW
		Power consumption	kWh
		Power quality	
	Air compressors	Power demand	kW
	Forklifts	Power demand	kW
		Run-time	Hour
	Water pumps	Power demand	kW
		Power consumption	kWh
Gas	Utility main	Energy	MMBtu
		Cost	$
		Price	$/MMBtu
Steam	Boilers	Steam flow	kLbs
		Steam temperature	°F
		Cost	$/kLbs
Water	Water pumps	Water flow	GPM
		Water pressure	PSI
		Water pumped	Gal

Cost Estimate

Figure 2 shows cost estimate of the winning vendor's proposal. Total cost is $126,000, includes $66,000 of base system (server and software) and $7,900 per monitoring point (metering hardware, installation, configuration). The base system cost will not significantly increase with the addition of monitoring points. The cost per monitoring point depends on existing meter equipment and the quality of metered data desired.

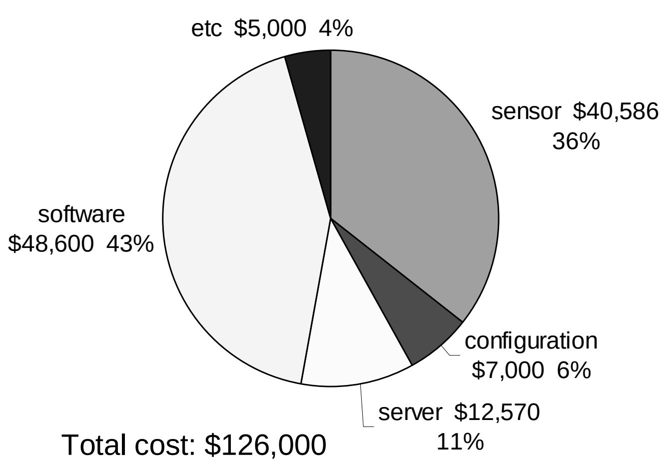

Figure 2: Breakdown of EEM Installation Cost

5. Post-Installation Analysis

LBNL conducted post-installation analysis for the use and trend data of the EEM. The analysis is based on the trend data and feedback from the users. From the users' perspective, the EEM is used for 1) energy saving verification and 2) daily system operational decision making.

The main intent of the EEM installation is to identify opportunities for increasing the effectiveness and energy efficiency, while reducing the operating costs, of the monitored systems. Once the energy saving and/or cost saving potential in the operation of a system is identified and quantified, plant personnel can take specific actions with confidence in the outcome. The ability to visually represent both the impact of current practice and the potential for improvement is a major asset in obtaining management approval for system improvements. The EEM can be built out incrementally over time to include measurement and analysis of other systems within the plant. Multiple facilities can also be connected into a corporate network via multi-site EEM installations.

The initial data can be used to establish a time series baseline for operations prior to the any system improvements. Data collected post-improvement may be used to establish a new baseline. Data collected over an extended period post-improvement can be used to trend the energy use and cost to production, as well as to identify opportunities to improve operational efficiency. At the time of this writing the measurement data is being collected and analyzed to establish a baseline, however preliminary analysis has already identified opportunities to make specific operational improvements.

An example of these operational improvement opportunities was revealed through preliminary analysis of the compressed air system. Currently, the air compressors are operated manually by the facility operator. Prior to the EEM installation, the operator did not have reliable data concerning compressed air output or demand for any specific time period. Therefore, the air compressors were operated in a fixed operational pattern designed to meet production needs without regard to efficient operation. After the EEM installation, the operator was able to check air compressor data on a daily basis, and decide how many compressors to operate to meet the facility's needs. The operator has found that the EEM quite useful in understanding the facility's operation.

Compressed Air System Analysis

We conducted additional data analysis for the compressed air system supply to look at the overall efficiency of the compressed air supply. Compressed air is supplied by eight compressors in a variety of sizes, brands, age, and capacity. As previously mentioned, control is achieved manually rather than through a sequencer or other coordinated control strategy. Two 100 hp rental compressors are added to this configuration during summer production season. Table 2 shows specification for each air compressor. The EEM measures the electric demand of each compressor with the exception of the rental compressors, and total airflow at the header (including the output of the rental compressors during the peak production months). The rental compressors were continuously operated for 24-hours a day at full load from August 1st to September 12th, 2005.

Table 2: Air Compressor Farm Specification

	Full Load CFM	Full Load HP	Full Load kW	Full Load Package kW[2]
Compressor #1	620	125	93	115
Compressor #2	442	100	75	92
Compressor #3	352	75	56	69
Compressor #4	352	75	56	69
Compressor #5	320	75	56	69
Compressor #6	320	75	56	69
Compressor #7	425	100	75	92
Compressor #8	425	100	75	92
Rented Compressor #1	450	100	75	92
Rented Compressor #2	425	100	75	92
Total	3256	725	540	668

Figure 3 plots total compressor power against total airflow with the compressor efficiency curve estimated from the compressor specification. Due to lack of power measurements for the rental compressors, these values were estimated based on the compressors' operational setting during the affected period. In Figure 3, the total power demand of the permanent compressor installation is shown in black, and total power demand of both the permanent and rental compressors (with extrapolated values for the rental units) is shown in gray.

The chart indicates that the compressors used 10 to 20% higher electricity demand than their efficiency curve. Another important finding from these data is that the maximum required airflow was around 3,300 cubic feet per minute (cfm), which is almost same as the total capacity of the permanently installed compressors. This indicates that this facility may be able to meet peak demand without the additional cost of the rental compressors. Even allowing for a margin of additional demand, it is unlikely that an extra 200 hp would be required. Since rental compressors are expensive to lease and operate, this could be a significant cost saving opportunity.

The trend data also revealed that Compressor #1, which has the highest efficiency in the compressor supply system, is offline more than 90% of the time. By assigning Compressor #1 to run as base load, the total compressor efficiency can be expected to increase. Thus, capturing compressor operational characteristics may help improve efficiency and reduce the cost of operation.

[2] There is difference between compressor motor nameplate ratings (hp) and actual compressor package kW. Most compressors have motors with 1.15 Service Factor (SF) rating. Also air cooled compressors have fan motors in the package driven by separate motors, thus increase the "Package Power" further. In this analysis, the factor of 1.24 which is calculated from Compressor #1's manufacture specification is applied to all the other compressors.

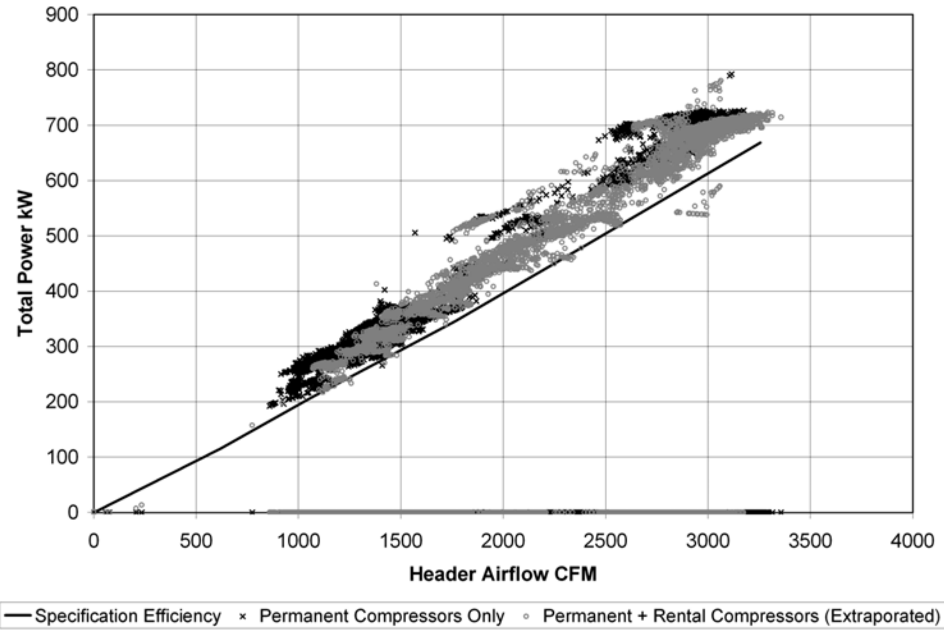

Figure 3: Compressor Efficiency Diagnostic Chart

6. Conclusion

The lack of immediate access to meaningful data is a significant barrier for plant personnel seeking to understand and improve the operational efficiency of plant systems. EEM systems offer great potential to help facility engineers and plant managers run their facilities more efficiently. However, the market for EEM is still immature, and not many products are available. Moreover, the customer awareness and demand for EEM system is low. Promotion of successful installations of EEM will help increase development of EEM market, and will eventually make energy management of industrial sector more efficient.

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